



INSTITUTE FOR DEFENSE ANALYSES

Ground Vehicle Fleet Health

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September 2007

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IDA Document D-3467
Log: H 07-001433

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PREFACE

This document was prepared under the “Technical Analysis for Ground Combat Platforms” task for the Director, Program Analysis and Evaluation (PA&E). The primary PA&E point of contact (POC) is Ms. Kathleen Conley. The Institute for Defense Analyses (IDA) POC is Dr. David Sparrow.

CONTENTS

PowerPoint Slides by Title:

Background and Summary (1 of 3)	1
Background and Summary (2 of 3).....	2
Background and Summary (3 of 3).....	3
Outline	5
Introduction	7
Context for Study of Vehicle Aging and Health	8
Problem Formulation	9
Analysis Approach	10
What Would Indicate Aging?	11
Summary of Introduction	12
OSMIS Data Analysis	13
What is OSMIS?	14
Applicability of OSMIS Database	15
OSMIS Data: M1A1 Usage	16
OSMIS Data: M1A1 Cost (\$)/Mile Averaged Over MACOMs	17
OSMIS Data: M1A1 Average Cost by Year	18
Conclusions From OSMIS Data	19
AMSAA Sample Data Collection (SDC) Analysis	21
AMSAA SDC Overview	22
AMSAA SDC Dataset Description	23
Analysis of AMSAA Data	24
AMSAA SDC Data: Number of NMC Records and Operational Miles	25
AMSAA SDC Data: NMC Records/Total Miles in Iraq vs. at Ft. Hood.....	26
Conclusions From AMSAA Data	27
Mission Capable Rates Data (GAO Report)	29
Applicability of Mission Capable Rates	30
Mission Capable Rates for M1 and HEMTT	31
Healing of Mission Capable Rates: March–September 2005	32
Conclusions From Mission Capable Rates Data	33

Other Observations and Conclusions	35
Other Observations	36
Summary	37
Backup Slides	39
Vehicle Aging – General Considerations	40
The Impact of Different Designs on Aging	41
Air Vehicle Aging	42
Ground Vehicle Aging	43
Tracking Vehicle Failure Mode Observables	44
RAND Analysis Summary	45
RAND Study: M1 Aging	46
RAND Study: Predicted Mean Failures of Selected Subsystems by Age (Ft. Hood, 180 Days)	47
RAND Study: 95% Confidence Bands for Model Predictions	48
RAND Study: Predicted Mean Failures by Tank Usage and Location	49
RAND Study: Selected Results	50
OSMIS Backup	51
OSMIS Data: M1A1 Density	52
OSMIS Data: M1A1 Cost (\$)/Mile by MACOM FY04	53
OSMIS Data: M1A1 Cost (\$)/Mile by MACOM FY05	54
OSMIS Data: HEMTT Usage	55
OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (1 of 3)	56
OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (2 of 3)	57
OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (3 of 3)	58
OSMIS Data: HEMTT Cost per System	59
OSMIS Data: HEMTT Cost per Mile	60
AMSAA Backup	61
AMSAA SDC Data: NMC Records vs. Miles	62
AMSAA SDC Data: Maintenance Man-Hours vs. Records	63
AMSAA SDC Data: Total Miles vs. Number of Total Records (M) From Primary Dataset	64
Glossary	GL-1



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Stress on Equipment

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Background and Summary (1 of 3)

A. Background

Many have speculated that harsh operational environments and the pace of operations may significantly shorten the serviceable lifetime of Department of Defense (DoD) vehicles. If true, such premature aging would necessitate a substantial increase in current supplemental appropriations or in post hostility investments to return the fleet to reasonable health. These concerns are particularly acute for combat and tactical ground vehicles.

Although the speculation seems plausible, information that would support a quantitative assessment of the problem's magnitude is scarce. Increased operating tempo (OPTEMPO) is widely reported, but even the current wartime OPTEMPO does not lead to high mileage. It is only high when compared with peacetime levels.¹ Maintenance expenditures have increased, but little information is available to assess whether the resulting increase in maintenance activity has kept pace with or fallen behind the Operation Iraqi Freedom (OIF)-related damage. After reviewing recent work by RAND and the Congressional Budget Office (CBO) and performing our own assessment of the available data, we find no analytical justification for excessive vehicle aging or for any new acquisitions or expanded procurements.

Press discussions of these issues have relied heavily on anecdotes and/or intuitive notions of ground vehicle "aging" and how this aging might be accelerated in Iraq. In addition to accelerated aging caused by harsh environments and usage, an inability of the maintenance activities to keep pace with the damage induced by heavier usage in a harsh environment might also lead to accumulating damage. In either case, we would expect to see evidence of this accumulating damage in some aspect of DoD operations and maintenance (O&M) activities.

The Institute for Defense Analyses (IDA) has reviewed available O&M data on select Army systems. This review included published Operating and Support Management Information System (OSMIS) data and portions of the Army Materiel System Analysis Activity's (AMSAA) Sample Data Collection (SDC).² We also looked at the trend in mission capable rates. The results are presented in this annotated briefing. In addition to our work, the CBO³ studied the Army's Reset program, and RAND⁴ studied vehicle aging in M1 tanks. The next slide summarizes the results of the CBO and RAND studies on vehicle fleet health. A synopsis of the IDA results follows the CBO/RAND study summaries.

¹ OIF mileage for HMMWV cargo/troop carriers has been in the range of 3,700 to 4,600 miles/year, contrasted to the 10,000 to 12,000 miles/year common for personal vehicles and the 100,000 annual mileage of new heavy-duty commercial trucks.

² OSMIS is the Operating and Support Management Information System used by the Army's Assistant Secretary for Financial Management, and AMSAA is the Army Materiel Systems Analysis Activity, part of the Army Materiel Command.

³ Congress of the United States. (September 2007). *Replacing and Repairing Equipment Used in Iraq and Afghanistan: The Army's Reset Program*. Congressional Budget Office (CBO) Paper, Publication Number 2809. Available: <http://www.cbo.gov/ftpdocs/86xx/doc8629/09-13-ArmyReset.pdf>

⁴ Fan, C. E., Peltz, E., and Colabella, L. (2005). *The Effect of Equipment Age on Spare Parts Cost: A Study of M1 Tanks*. RAND Corporation Technical Report TR-286. Available:

http://www.rand.org/pubs/technical_reports/2005/RAND_TR286.sum.pdf and

Peltz, E. Colabella, L. Williams, B. and Boren, P. (2004). *The Effects of Equipment Age on Mission-Critical Failure Rates: A Study of M1 Tanks*. RAND Corporation Monograph Report MR-1789. Available:

http://www.rand.org/pubs/monograph_reports/2005/MR1789.sum.pdf



Background and Summary (2 of 3)

B. CBO/Rand Studies on Vehicle Health

The CBO documented that OPTEMPO in Iraq and Afghanistan is systematically higher than that of the Active Army (AA) Peacetime OPTEMPO. However, this result is largely due to the very low peacetime OPTEMPO of U.S. Army equipment. Most of these systems were designed during the Cold War for use in conflicts that would have a significantly higher OPTEMPO than that which occurs currently in Iraq and Afghanistan. The CBO finds that the current OPTEMPO can be sustained for a decade or more.⁵

The RAND study on M1s established a correlation between year of manufacture and failure rates. This generally supports the notion of “aging,” but individual component aging and vehicle aging cannot readily be distinguished. (Component aging leads to isolated failures that can be addressed by direct component replacement, with no increase in failure rate. Vehicle aging leads to increasing failure rates of multiple components—failure rates that continue after component replacement. For example, worn tires can be replaced with new tires; however, a bent frame that prevents alignment can lead to repeated rapid tire failure. Thus, distinguishing between component aging and vehicle aging is necessary when making repair vs. replace decisions.)

The RAND data reveal significant variability in failure rate by location. This includes variability within Major Commands (MACOMs) with multiple installations. The underlying data also show significant year-to-year variability.

C. IDA Study Results

IDA, as RAND did, found that the O&M data from Iraq showed large variability by command and by year. This variability applied to combat and tactical vehicles. This obscures trends in the data, particularly data from a relatively short period such as OIF.⁶ In particular, no deterioration is observed by comparing experience from 2005 with earlier years.

⁵ CBO reports the Up-armored High Mobility Multipurpose Wheeled Vehicle (UAH) as an exception to this. The UAH is relatively new and still in procurement. For this case, continued procurement or procurement of a replacement such as a Mine Resistant Ambush Protected (MRAP) vehicle would be necessary to achieve the numbers necessary to sustain the current operating tempo (OPTEMPO) for a decade.



Background and Summary (3 of 3)

IDA also found that the wartime OPTEMPO is modest in miles per year. [The relatively small number of High Mobility Multipurpose Wheeled Vehicles (HMMWVs) at Echelons above Division are an exception, running about 2,300 miles/month.] Wartime and peacetime maintenance experiences appear similar. However, the suspension systems on tanks represent a notable exception. Engines and transmissions are the cost drivers on most vehicles, and their repair rates are comparable to peacetime rates. Electronic systems do not appear as cost drivers.

Mission capable rates across the Army combat and tactical fleets dropped beginning in 2003, bottomed out in 2004, and largely healed by 2005. These rates are strongly influenced by logistics and thus can only be an indirect indicator of fleet health. Nevertheless, the rapid healing suggests improvements in the logistics process and is inconsistent with premature vehicle aging.

When we put these results together, we conclude that neither the observed O&M burden nor vehicle “aging” appears to provide justification for new acquisitions or expanded procurements. In other words, while the data show a need for expanded repair efforts to parallel increased usage, no analogous evidence suggests a need for recapitalization in terms of new starts or expanded procurement.

D. Summary

The nature of the “strength-limited” design of ground vehicles eliminates the possibility of a general argument in favor of vehicle replacement. This is reinforced by the fact that the vehicles are not yet approaching their design life, based on much more severe Cold War scenarios. Finally, we found no compelling evidence of an increasing O&M burden with time since the start of OIF. The negative formulation here is deliberate: none of the available data relate directly to the question of recapitalization vs. repair. Further, the available data show great variability by command, by location, and over time. A methodical data collection effort aimed at addressing the impact of OIF will be necessary to establish the extent of damage and the need for vehicle replacement.

⁶ During RAND’s review of our work, they raised substantive issues concerning the quality of the data in the OSMIS and the AMSAA Sample Data Collections (SDCs). For our analysis, we generally accepted the data and determined what it would show.



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Outline

- I. Introduction
- II. OSMIS Data Analysis
- III. AMSAA Sample Data Collection (SCD) Analysis
- IV. Mission Capable Rates Data (GAO Report)
- V. Other Observations and Conclusions
- VI. Backup Slides



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Introduction



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Context for Study of Vehicle Aging and Fleet Health

- During 2003–2006, approximately \$100B in supplemental appropriations was provided for increased O&M expenditures, primarily because of OIF activities
 - Most of the expenditures were tied directly to increased OPTEMPO
 - Approximately \$8B in supplemental spending has been targeted for depot maintenance (as have some procurement funds), part of which has been aimed at restoring useful life to the Army's vehicles
 - Estimates suggest that restoration cannot be completed until 2 years after the end of OIF because of logistics constraints on returning vehicles
 - The Army estimates the OIF-related backlog of unexecuted depot maintenance at \$3B to \$4B
- Despite these expenditures, no generally agreed means exist to characterize fleet health or the remaining useful life for ground vehicles based on either general theoretical considerations or on the currently collected data
 - Such means are a prerequisite for estimating the needed work to restore service life

8

The Army recognized the importance of the ground vehicle fleets' health early in Operation Iraqi Freedom (OIF). In 2004, efforts were made to quantify the possible long-term health effects on vehicle useful life. Anecdotal evidence indicated that OIF was increasing wear and tear on the vehicles. Desert Storm experience suggested that the vehicles would experience residual effects because of desert operation—beyond that which could be handled through increased maintenance to parallel this increased usage. The magnitude of these effects was unclear.

One way to quantify residual effects would be to track vehicle reliability, comparing systems that had deployed and returned with similar populations that had remained in the United States. Plans to collect and analyze data in this sort of longitudinal study were proposed by RAND and the Army Materiel Systems Analysis Activity (AMSAA) and agreed to at a Department of Defense (DoD) meeting in early FY05. The plans did not come to fruition. As a result, data that specifically address the scale of "vehicle aging" or deteriorating fleet health as these conditions relate to OIF are not available. Also not available are general observables that allow the characterization of remaining life for ground vehicles in the way that fatigue-related crack growth can be used for aircraft.



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Problem Formulation

Without a clear and explicit definition of aging or any data collected specifically to assess the state of aging, IDA was asked the following question:

What can be learned about fleet health from whatever data are available?

9

Without a clear and explicit definition of aging or any data collected specifically to assess the state of aging, IDA was tasked to see what could be learned from the data that were available. In this context, “aging” means loss of useful life in vehicles or in a vehicle fleet. Fleet health is sometimes used to express the same concept. The “Backup Slides” contain a general discussion of vehicle aging, with comparison of air-vehicle and ground-vehicle mechanisms.

This tasking led to a somewhat “free-form” examination of Army reliability data to determine if any clear indicators emerged. It is unclear *a priori* what specific features of the reliability data (e.g., part types or classes of parts) might provide insight into aging.

IDA also looked at mission capable rates. As with reliability, the mission capable rates depend upon the schedule and quality of maintenance and the resources and performance of the logistics support. Short-term changes in mission capable rates are unlikely to be caused by changes in reliability. Longer term changes are influenced by changes in logistics and in the practices of the Army Reset program.



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Analysis Approach

- Chose system to emphasize: the M1 Abrams main battle tank
 - Essential combat system no longer in production
 - Capitalized on work by RAND
 - Also looked at HEMTTs in detail and other systems more broadly
- Available data and studies
 - O&M data from OSMIS and AMSAA's SDC
 - Army mission capable rates
 - A 2004 RAND report: *The Effects of Equipment Age on Mission-Critical Failure Rates: A Study of M1 Tanks*
 - A 2007 CBO report on the Army Reset program: *Replacing and Repairing Equipment Used in Iraq and Afghanistan: The Army's Reset Program*

10

The initial approach was to focus on a single system: the M1 Abrams main battle tank. The system is an essential combat system but is no longer in production, so “aging” problems cannot be addressed by extending procurement. Mothballed Abrams could be returned to duty, however.

A second reason for selecting the Abrams is that this tank is the subject of a comprehensive RAND study investigating reliability over time. The basic RAND approach was to examine contemporary reliability as it relates to the year of manufacture. This is “aging” in the sense of a literal calendar year. Most of the stress-on-equipment work has used aging or accelerated aging in the sense of the figurative “loss of remaining useful life.” By analogy, the former is the time since birth, while the latter is the time remaining until death.

We also used data from the Army’s Operating and Support Management Information System (OSMIS) on M1s and Heavy Expanded Mobility Tactical Trucks (HEMTTs), the AMSAA Sample Data Collection (SDC) on M1s, and the Army’s reported mission capable rates on multiple systems. While this report was being prepared, the Congressional Budget Office (CBO) published a study on the Army’s Reset program, and we have included a summary of the CBO results in our Background and Summary section.



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What Would Indicate Aging?

- “Aging” indicators
 - Increases in cost per mile:
 - In OIF, compared with CONUS
 - Over time, during OIF
 - Increases in part failure rate
 - Mission-critical failures
 - Non-mission-critical failures
 - Differences in O&M activities between CONUS and OIF vehicles
 - Decreases in mission capable rates for systems
- All these measures are indirect
- All these measures are confounded by other factors not related to fleet health

11



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Summary of Introduction

- No directly applicable data or agreed-upon theoretical descriptions are available to characterize or estimate the effect of OIF on ground vehicle fleets
- IDA's tasking was to determine what could be learned from the available data
- Data on O&M activities and on mission capable rates were examined for indications of aging induced by OIF operations
- Results from specific data sets follow

12

An example of directly applicable data would be a longitudinal study comparing the operations and maintenance (O&M) requirements of vehicles returning from OIF with those of similar vehicles that had never been sent to Iraq. Without such controlled data gathering, the indications will be indirect.



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OSMIS Data Analysis



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What is OSMIS?

- OSMIS is the Operating and Support Management Information System
- Historical database of operating and support information for approximately 1,400 Army weapon and materiel systems
- Analytical tool *supporting* the DoD community in the areas of acquisition, budget, costing, and logistics
- System data includes
 - Class IX demands
 - Activity data (miles/hours)
 - Parts (NSN level) and fuel
 - Ammunition
 - Intermediate maintenance
 - Depot maintenance
 - Year of manufacture
- Data can be filtered by activity
 - CONOPS: Contingency operations only
 - Non-CONOPS: Peacetime training operations only
- www.osmisweb.com

Reference: K. O'Brien and K. Kuck. (May 10, 2006). *Operating and Support Management Information System (OSMIS) for the Institute for Defense Analyses*

14

In 1974, the Office of the Secretary of Defense (OSD) initiated a program to improve the visibility of and control over materiel system operations and support (O&S) costs.¹ This program required the secretaries of the military departments to implement a management information system to report the actual O&S costs for currently fielded major defense systems.

The Operating and Support Management Information System (OSMIS), the Army's response to this requirement, is managed by the U.S. Army Cost and Economic Analysis Center (USACEAC) and is the U.S. Army's source of historical O&S cost information for more than 500 systems deployed in tactical units: Active Army, National Guard, and Army Reserve.

OSMIS has added a new query option in which data beginning in FY02 can be observed in three different ways: (1) contingency operations only, (2) peacetime training operations only, and (3) the sum of both. This option was added because of the escalating scope of contingency operations [Operation Enduring Freedom (OEF) and other Central Command (CENTCOM) deployments] and the resultant effect these operations have on demand, activity, and density data.

¹ Fuel is not included in costs and can be deduced from mileage, rather than directly recorded.



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Applicability of OSMIS Database

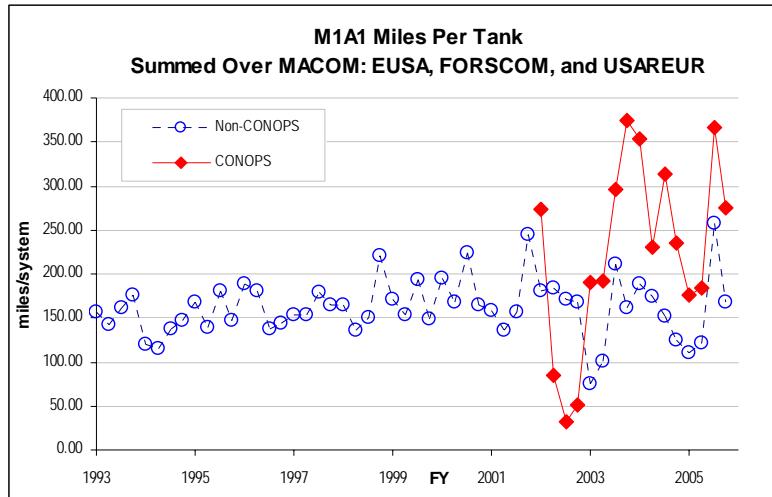
- Data are on fleetwide parts usage
 - Intended to guide “next-years” parts orders
 - May reveal aging or fleet health issues that have fleetwide manifestations
 - However, no data available on what went wrong or why
- Approach: Pursue fleetwide comparisons of
 - CONOPS and Non-CONOPS experience: What drives cost in CONOPS and Non-CONOPS? Is there a time dependence in parts’ requests?
 - Two systems: M1A1 tanks and HEMTTs

15

In the data presented in this briefing, “fleetwide” does not mean the entire fleet; rather, it means data summed over vehicles aggregated by unit. In our analyses, we used aggregations by Major Command (MACOM).

- **Advantages:**
 - High number of statistics over a broad set of platforms and parts over the whole of the Army.
 - Ease and speed of making queries.
 - Useful in determining average costing behavior over the fleet.
- **Disadvantages (the issue is incomplete data):**
 - Platforms are tracked by unit, not by tail number.
 - Individual parts and condition are not tracked (wear vs. battle damage).
 - Absolute miles are not known (or cannot be considered reliable) because odometers can be and are replaced and this information is not entered into the OSMIS database.
 - Monthly management reports contain mileage and year of manufacture, but this information is not available for all years that parts-demand data exist for individual units. In addition, the year of manufacture and mileage are often not included in the report.
 - Maintenance practices are not known.
 - Parts obtained outside the nominal logistics chain—a common occurrence during contingency operations—will not be entered into the OSMIS database.
 - Reset or overhaul information is not known.

OSMIS Data: M1A1 Usage



The average CONOPS miles per tank is nearly 50% more than Non-CONOPS

16

The graph in this slide displays the M1A1 quarterly operating tempo (OPTEMPO) (miles/system) summed over three MACOMs: the Eighth United States Army (EUSA), the U.S. Army Forces Command (FORSCOM), and the United States Army Europe (USAREUR) for each quarter from 1993 through the fourth quarter of 2005.² [From 1993–2001, the peacetime (training) OPTEMPO was about 150 miles/tank/quarter or 600 miles/year.]

- Blue Open Circles: Non-CONOPS miles/system as a function of Fiscal Year (FY)
- Red Diamonds: CONOPS miles/system as a function of FY.

Tracking the M1A1 OPTEMPO gives evidence of real-world events, including the Global War on Terrorism, the Onset of OIF, and the March to Baghdad. We want to determine if “vehicle aging” is a similar real-world event that shows up in the data.

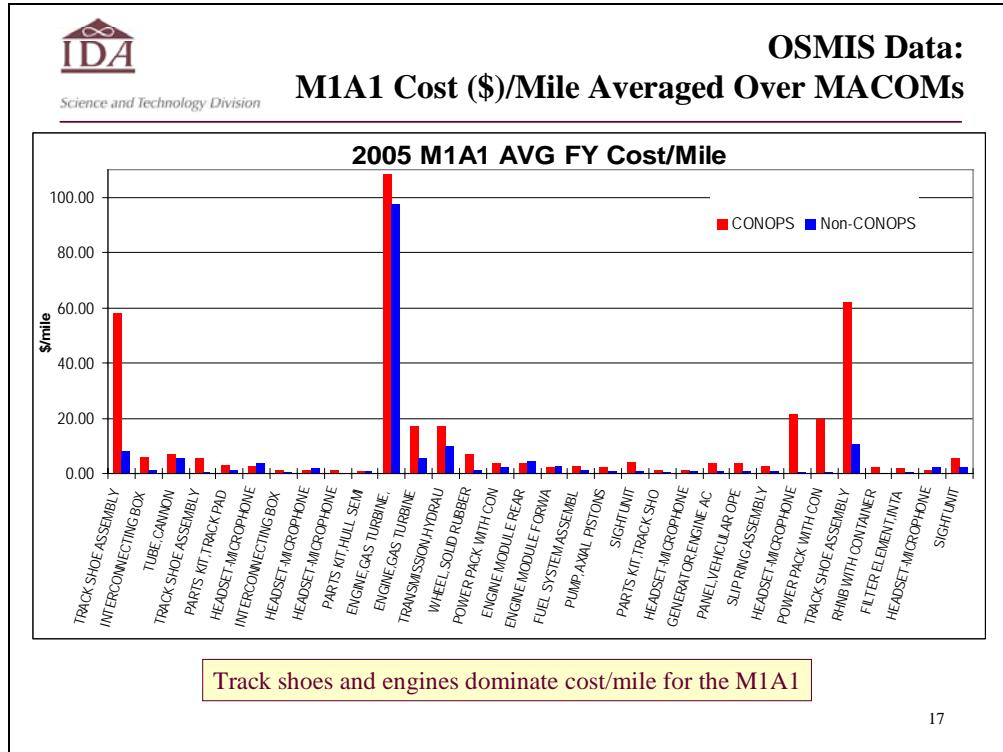
From FY 2002 through 2005, the average CONOPS usage in miles is about 50% more than the Non-CONOPS usage for the 3 MACOMs named above (see table to the right).

Similar results are observed for HEMTT.

OPTEMPO by Quarter (miles/system)

YEAR	CONOPS OPTEMPO	Non-CONOPS OPTEMPO
2002	272.91	180.23
2002.25	84.98	184.59
2002.5	31.97	170.95
2002.75	51.32	167.80
2003	189.72	75.35
2003.25	192.64	100.95
2003.5	296.64	211.71
2003.75	373.84	161.56
2004	353.33	189.09
2004.25	230.06	173.98
2004.5	313.62	152.34
2004.75	235.58	125.14
2005	176.73	110.52
2005.25	184.57	121.08
2005.5	365.95	257.46
2005.75	274.71	168.65

² These are the three MACOMs with non-zero CONOPS usage during this period (CONOPS = concept of operations).

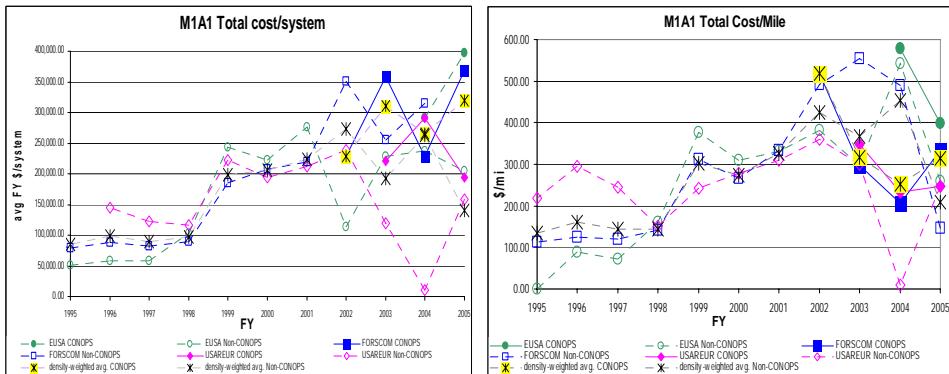


The graph in this slide displays the 2005 density-weighted average cost (\$) per mile for the top cost-driving M1A1 parts. Duplicate part names refer to different national item identification numbers (NIINs).

The CONOPS cost (\$) per mile (red bars) appears to be systematically higher than the corresponding Non-CONOPS cost (blue bars), with only a few exceptions. Track shoes and engines dominate the cost per mile. The track-shoe-related costs per mile are nearly 10X higher. This difference will drive cost but is not an indicator of aging because this effect is mitigated by installing new parts. If “normal” operations are resumed, the tires and parts return to “pre-CONOPS” behavior.

HEMTT trends are similar (see “Backup Slides”). Engines, tires, and transmissions are the top three cost drivers. All these elements have higher CONOPS cost (\$)/mile than that for Non-CONOPS.

OSMIS Data: M1A1 Average Cost by Year



MACOM cost/system behavior tracks before onset of CONOPS.
After CONOPS start, the scatter obscures possible trends

18

The graph on the left shows the total cost approximated by the sum of the costs of the top 50 consumable and repairable parts for each MACOM in each year and the density-weighted average of the total costs. The average total cost per tank is higher during CONOPS in 2003 through 2005.

The graph on the right shows the total cost per mile, estimated as the sum of the costs of the top 50 consumable and repairable parts for each MACOM in each year.³ The 2005 total cost per mile is higher during CONOPS than Non-CONOPS; however, this result does not hold true for 2003 or 2004.

For the most part, the cost behavior is similar across MACOMs and from year to year in the earlier years (before the onset of CONOPS). Later, the scatter in the CONOPS data by MACOM obscures any possible trends. The lack of systematic differences between CONOPS and Non-CONOPS and the lack of a trend over time preclude an aging analysis.

HEMTT shows similar behaviors (see “Backup Slides”).

³ FORSCOM deployed in 2002 (before OIF), USAREUR deployed in 2003, and EUSA deployed in 2004.



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Conclusions From OSMIS Data

- Increase in OPTEMPO miles during contingency operations
 - For M1A1, the 2005 the average usage per year (EUSA, FORSCOM, and USAREUR): CONOPS = 1,000 miles/tank; Non-CONOPS = 660 miles/tank
 - For HEMTT 2003–2005, the average usage per year: CONOPS ~ 2,200 miles/truck; Non-CONOPS ~ 1,500 miles/truck
- The leading cost drivers across all MACOMs—all years, CONOPS and Non-CONOPS—are engines and track shoes for M1A1 and engines and tires for HEMTT
- The density-weighted total cost per system seems to show an increased cost during contingency operations (2003–2005)
- Yet, tracking the cost per mile shows no conclusive evidence of increased cost during contingency operations
- The cost per system and cost per mile show a large variability across MACOMS as a function of time
 - This is consistent with a RAND study* that also showed significant variability of tank part failure rates depending on location
- No evidence of fleet deterioration or vehicle aging

* Peltz, E. Colabella, L. Williams, B. and Boren, P. (2004). *The Effects of Equipment Age on Mission-Critical Failure Rates: A Study of M1 Tanks*. RAND Corporation Monograph Report MR-1789



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AMSAA Sample Data Collection (SDC) Analysis



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AMSAA SDC Overview

- SDC on Abrams tanks from NTC, Ft. Hood, and OIF

Recorded data:

- Miles [sometimes conditions], part failures [what, how (e.g., battle or wear), when], repairs [what, how, when, how long, who], part delivery time, year of maintenance, operational miles, more ...
- Detailed data set that potentially allows one to determine Ao, MTTR, and MTBF at the vehicle level
- There is a “record” for each maintenance action. An NMC record is associated with correcting a situation that left the vehicle non-mission capable.

- Data not recorded or missing:

- Absolute mileage, operational hours on turbines and generators, reset/upgrade/overhaul platform, unit and command

- In the analysis, we extracted a subset of these data on the *same* tanks operated at

Ft. Hood and in Iraq. This led to

- Reduced numbers of vehicles needed to obtain a set of tanks with maintenance data in both locations
- Reduced impact of unknown variability in external conditions, emphasizing age as the most significant variable

22

The AMSAA SDC was provided by Henry Simberg (AMSAA). We examined a sample collection of M1 Abrams tanks from National Training Center (NTC), Ft. Hood,⁴ and OIF (Iraq). This represents only a small portion of the entire SDC responsibility.

The data contain maintenance and operations records, with information about individual tanks over varying periods of time. Smaller subsets of the SDC were created to look for certain trends and indicators between tanks in CONOPS (Iraq) and Non-CONOPS (Ft. Hood).

The idea of the analysis was to compare the reliability of tanks in OIF and in the United States. Accelerated aging should be evidenced by increased failure rates (of the same tanks). Comparing the same tanks is important because of the large scatter in failure rates between different tanks (even in the same location).

⁴ Ft. Hood is located in Texas.



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AMSAA SDC Dataset Description

Universal dataset: Abrams tank (M1) records from NTC (1992–2004), OIF (2003–2004), Ft. Hood (2000–2002)

Primary Dataset: All tanks that had been in OIF and another location (Ft. Hood, NTC) – “Iraq vs. Non-Iraq”

Primary Subsets: Maintenance and operations records for all tanks that had been in OIF and at Ft. Hood

Universal Dataset			
	Ft. Hood	Iraq	NTC
Years of data	3	2	12
Total miles	210K	273K	1,738K
Maintenance records	20K	4K	126K
Operations records	3,000	800	7,000

Primary Subset	
Intersection of Records From Iraq and Ft. Hood	Number of Tanks
Same serial number in maintenance records	119
& w/corresponding operations records	73
& w/non-zero mileage in both locations	47

23

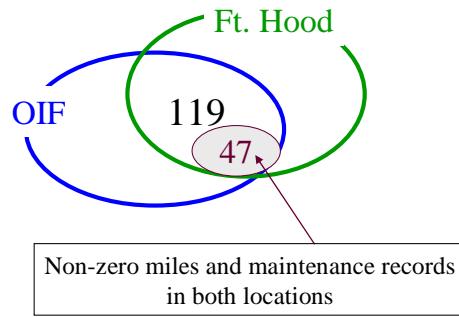
How did we get left with 47 tanks? These tanks have maintenance records and non-zero mileage in Iraq and at Ft. Hood.

- One hundred nineteen tanks have at least one maintenance record in Ft. Hood and at least one maintenance record in Iraq. However, these maintenance records do not contain any mileage data. The mileage is contained in the corresponding operations records. Of the 119 tanks, 73 have operations records for both Ft. Hood and Iraq.
- Perusing the operations records shows that some tanks have one record from Ft. Hood and the others from Iraq. Some of the tanks with the one record from Ft. Hood have zero miles for that record.
- The operations records from Iraq, if checked by dates, indicate specific times that groups of tanks came in. During those times, it appears either the mileage was taken from all of them or none of them. Twenty six tanks had operations records but no mileage data for Ft. Hood or Iraq. Four tanks had operations records but no mileage data for either location.

Analysis of AMSAA Data

The Objective:

- Find a set of tanks that have data (non-zero miles) in Iraq and at Ft. Hood
- Compare the number and type of NMC records and the usage between tanks at Ft. Hood and in Iraq
- Harsh usage and accelerated aging in OIF should be evidenced by higher corresponding failure rates



Location	Tanks	Miles	NMC Records
Ft.Hood	119	90K	2,536
Iraq	119	140K	1,152

24

We looked for the number of non-mission capable (NMC) records (including those for individual parts) found in maintenance records at Ft. Hood and OIF as an indicator of accelerated aging.⁵

This slide shows the total mileage, calculated as the sum of the mileage listed in the tank's operations records by location.

⁵ As mentioned on the previous slide, 119 tanks had maintenance records at Ft. Hood and Iraq.



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AMSAA SDC Data: Number of NMC Records and Operational Miles

From the intersection of Ft. Hood and Iraq data, total number of tanks that have non-zero recorded operational mileage: 47

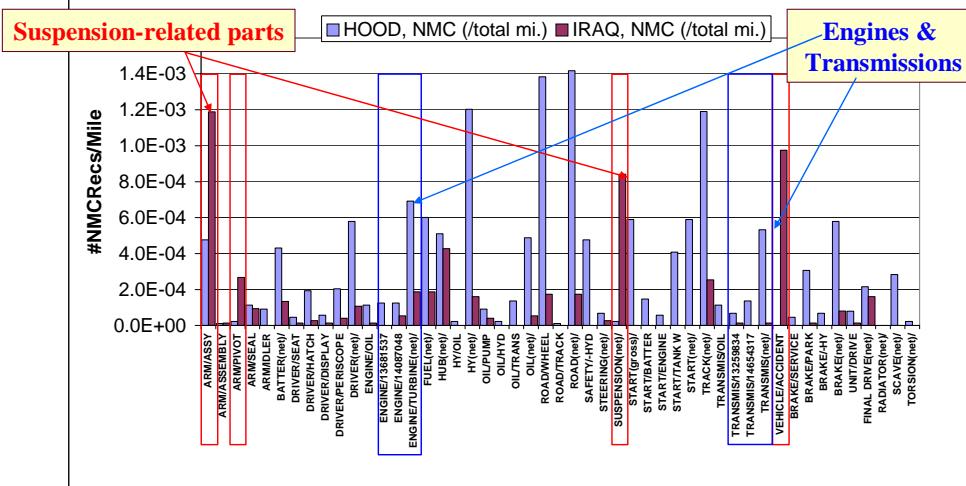
	Ft. Hood	Iraq
Total Miles	~ 89K	~ 72K
Total Maintenance Records	~ 5,000	~ 600
Total NMC Records	~ 2,300	~ 260
Years (Dates)	3 (2000–2002)	2 (2003–2004)
Average Miles/Year/Tank	631	766
Total Records/Total Miles	0.056	0.008
Total NMC Records/Total Miles	0.026	0.004

The same tanks in Ft. Hood show over six times the number of NMC records (per mile) than those in Iraq

25

Forty seven tanks have maintenance and operations records both in Iraq and at Ft. Hood indicating non-zero operational mileage for both locations. Despite the reduction in the number of tanks, we have an abundance of miles and maintenance records. Note that tanks in Ft. Hood fail about six times more often than those in Iraq. A possible explanation may be that not all the NMC failures that would be reported in Ft. Hood are reported in OIF. If this were the case, however, it is expected that we would see the evidence of tanks needing substantial repairs at some point (in time or miles). We do not observe that. Note that the ratio of the NMC records to total records is about the same at Ft. Hood (0.46) and in Iraq (0.43).

The difference in the Iraq mileage between the 119 tanks and the 47 tanks resulted because more tanks did a lot of miles in Iraq but have no recorded miles at Ft. Hood because of the lack of an operations record at Ft. Hood or zero recorded miles at Ft. Hood. Forty six tanks have about 40K Iraq miles and no Ft. Hood operations records, and another 26 tanks have operations records at Ft. Hood with 0 miles recorded and 27K Iraq miles recorded.

AMSAA SDC Data:
NMC Records/Total Miles in Iraq vs. at Ft. Hood
NMC Records per mile as a function of part type


In Iraq, only parts related to the suspension fail more often than those in Ft. Hood. The rest of the parts, including engines, fail less frequently. [This is contrary to the OSMIS conclusions, which may be a sample size effect (i.e., 47 tanks vs. fleet data)]

26

Taking the 47 tanks and analyzing their maintenance records for keywords, part numbers, and location, we compare the number of NMC records with that keyword or part number divided by the total number of miles driven in that location.

The only parts that fail more often (per mile) in Iraq than at Ft. Hood are suspension-related parts. In almost every other category, Ft. Hood has a higher number of NMC records/mile rate than Iraq. Even engine and transmission parts—high cost drivers from OSMIS data—fail more in Ft. Hood than in Iraq. Anecdotal reports early in OIF indicated that suspensions were failing more often than before the war. This seems to confirm those reports. It also provides another example of markers of real-world events appearing in the data.

The results in this plot differ from the OSMIS results, which show greater engine replacement in CONOPS than in Non-CONOPS. The AMSAA data are recorded from a small subset, so the difference may simply result from the highly variable nature of the data.



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Conclusions From AMSAA Data

- The largest number of failures (per mile) in Iraq are due to suspension parts. This is likely a result of the increased fraction of time driving on paved roads
- Most of the remaining failures (per mile) in Iraq are lower than those observed in the Ft. Hood data
- No widespread difference exists in maintenance records or maintenance man-hours between Iraq and Ft. Hood (see Backup slides)
- For comparable mileage, the average rate of NMC records (failures) per mile is lower in Iraq than at Ft. Hood
- *The reported data show differences between Ft. Hood and OIF but do not support the assertion of accelerated tank aging in OIF*

27

Tanks are designed to go cross country; thus, harder roads induce more damage on tanks' suspension systems. For example, track shoes wear out much faster.



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Mission Capable Rates Data (GAO Report)*

* GAO-06-141. (October 2005). *MILITARY READINESS: DOD Needs to Identify and Address Gaps and potential Risks in Program Strategies and Funding Priorities for Selected Equipment.*



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Applicability of Mission Capable Rates

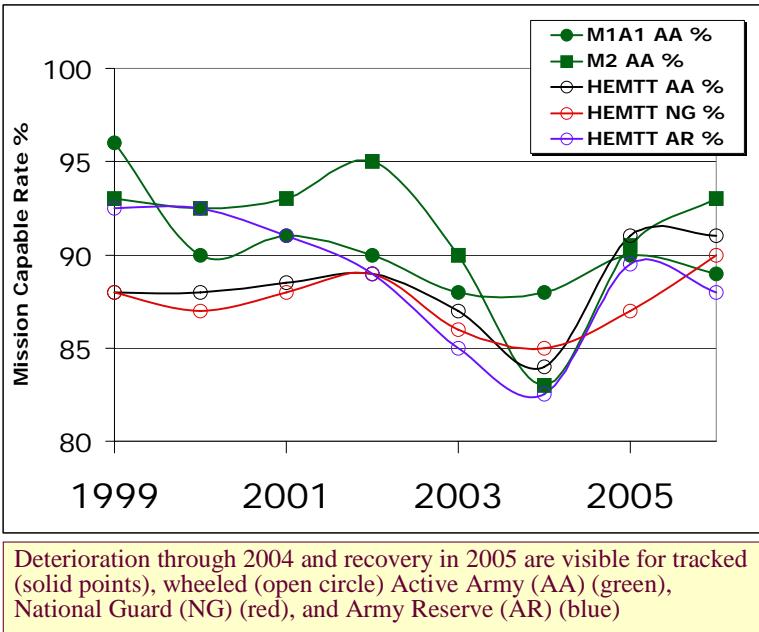
- Mission capable rates are measures of material condition. They indicate that the equipment can perform at least one and potentially all of its designated missions
- Available reports cover many vehicles types and large numbers of each
 - Reporting is now monthly
 - Yearly time history available from GAO reports
 - However, mission capable rates are subjective
- Expect reports to shed light on overall fleet health
 - Insight into proper scale of reset requires level-of-effort history and mission-capable history
 - Logistics effects on mission capable rates are large
 - Do not expect insight into aging per se
- Approach
 - Look at Active Army M1A1s for continuity
 - Add Active Army M2s and Active Army/National Guard/Army Reserve cargo HEMTTs

30

Government Accountability Office (GAO) report:

GAO-06-141. (October 2005). *MILITARY READINESS: DOD Needs to Identify and Address Gaps and Potential Risks in Program Strategies and Funding Priorities for Selected Equipment.*

Mission Capable Rates for M1 and HEMTT



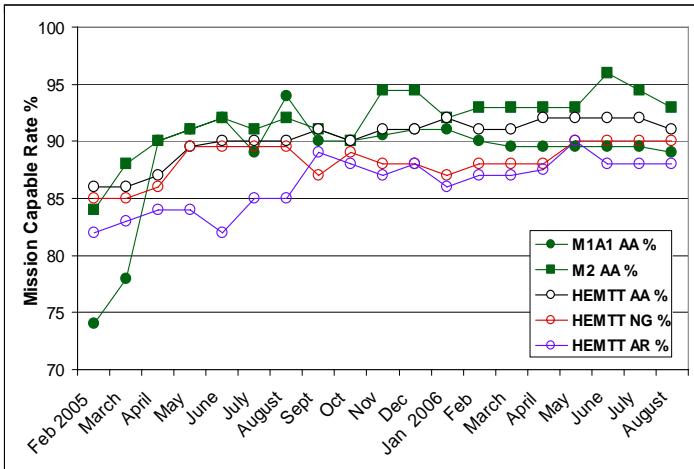
31

Mission capable rates are measures of materiel condition and indicate that the equipment can perform at least one and potentially all of its designated missions.

This slide shows mission capable rates for five selected families of vehicles. Data are from year end for 1999–2005. Data from 2004 and before was from the previously mentioned GAO report: GAO-06-141. (October 2005). *MILITARY READINESS: DOD Needs to Identify and Address Gaps and Potential Risks in Program Strategies and Funding Priorities for Selected Equipment*.

The 2005 data are from the August 2006 Army submission to Materiel Readiness and Maintenance Policy (MR&MP). The data were read from charts and may be off by 0.5%. The five systems were chosen because they were common to both data sets. They include tracked and wheeled systems and Active Army (AA), National Guard (NG), and Army Reserve (AR) fleets of the same (HEMTT) vehicle.

Healing of Mission Capable Rates: March–September 2005



From March 2005 until September 2005, mission capable rates climb to near the 90% of the Department of the Army goal. The National Guard and Army Reserve HEMTTs tend to lag after that point, but the Active Army systems are reported to do well. (As a partial explanation, depot capacity, measured in man-hours, grew 28% from FY03 to FY04 and ceased being a limiting factor in FY05.)

32

The graph in this slide plots the February 2005 to August 2006 data on mission capable rates submitted by the Army to Materiel Readiness and Maintenance Policy (MR&MP) for the same 5 systems as those on the previous slide.

With the exception of the NG HEMTTs “hiccup,” all the vehicle fleets were essentially at the 90% goal by September 2005. As of March 2005, the M2 Bradley’s had already healed, whereas the M1A1s lagged another month. Improvement in the HEMTT fleet occurred during the March 2005–September 2005 time period. The NG and AR HEMTTs tend to lag after that point, but the AA systems do well.



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Conclusions From Mission Capable Rates Data

- Clear decrease in mission capable rates in 2003 and again in 2004
- Rates largely healed by 2005
- Logistics affected both trends
- No evidence of problems with fleet health or vehicle aging

Rapid deterioration followed by rapid healing suggests that logistics has been the driver and is inconsistent with deteriorating fleet health



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34



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Other Observations and Conclusions



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Other Observations

- “High” wartime OPTEMPO still modest mileage per year
 - Per CBO: OPTEMPO low compared to Cold-War scenarios; sustainable for a decade
- Variability between commands and locations may be linked to maintenance and operational practices
- O&S cost is not likely to justify new acquisitions
 - Keep replacing engines/track shoes or tires
- Electronics are not a major cost driver

- No observable defect for ground vehicle aging is analogous to that of crack growth for aircraft aging
(No easy way to distinguish part life and vehicle life)
- OSMIS and AMSAA data provide no evidence for vehicle aging due to OIF activities
 - Variability in experience a persistent problem
 - In RAND results, vehicle aging effects are smaller than the variation observed by location and command
 - OSMIS and AMSAA failure rates give conflicting results
- “Healing” of the mission capable rates
 - Consistent with establishing fleet health
- Uncertainties in the data are large enough to not exclude that the Army is behind in their maintenance budget

37

For ground vehicles, no model is available to relate environmental conditions and driving cycle to age accumulation. For aircraft, models are available that allow crack length to be computed as a function of loading and environmental conditions.



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38



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Backup Slides



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Vehicle Aging – General Considerations

Vehicle aging can be conceptually defined as the loss of the vehicle's remaining useful life, which is defined by safety, performance, or economic measures

- In air vehicles, useful life is defined by
 - Accumulated fatigue damage and corresponding reduction in flight safety
 - Performance degradation
- In ground vehicles, useful life can be considered as a period of operation in accordance with vehicle's performance and reliability design specifications. Aging is evidenced by
 - Persistent increase in vehicle failure rates (replaced new parts fail more often than similar parts in new vehicles) and corresponding increase in O&S costs
 - Performance degradation



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The Impact of Different Designs on Aging

- Consider three classes of designs
 - 1. Single critical part controlling aging
 - Replace system when critical part fails or is unsafe
 - 2. Many important parts with decoupled lifetimes
 - There is no aging
 - Replace parts as they fail
 - 3. Many important parts with highly coupled lifetimes
 - Aging (without failure) of some parts affects the failure rate or performance of other parts
 - Part deterioration is “coherent” across vehicle
 - Replacing parts as they fail may not be effective; leads to need for vehicle reset or replacement (as opposed to component repair or replacement)
- Repair records might provide evidence of aging
 - Aging means that the vehicle’s condition is such that its reliability continues to decrease, as evidenced by a persistent increase in parts replacement rate (and corresponding maintenance cost) per mile and/or hour of operation

41



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Air Vehicle Aging

- Designs are usually fatigue limited
- Aging is controlled by fatigue life of critical parts
- Aging can be quantified by measuring fatigue damage. The observable parameter is crack growth
- Primary exceptions to aging-induced loss of remaining life are accidents

42



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Ground Vehicle Aging

- Design philosophy and damage mechanisms differ from those of aircraft
- Designs of major components are strength limited. Wear- and shelf-life-limited components (i.e., tires, shock absorbers, batteries, and so forth) are designed to be replaced as needed
 - Critical parts are rarely fatigue limited
 - Vehicle lifetime and part lifetime are distinct
- Life-limiting damage mechanisms are many
 - Fatigue, wear, corrosion, overstress failures (plastic deformation, buckling, bending, and so forth) can contribute
- No fatigue observables for ground vehicle aging are analogous to crack growth for aircraft



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Tracking Vehicle Failure Mode Observables

	Drive Train	Suspension	Chassis	Electrical
Thermal (Microscopic)	Burned bearings, heat failures in engine and transmission. Burst seals Evidence of accumulating metal in oil?	Burned wheel bearings and corroded shock absorbers, springs, leaf springs, wheel bearings	Corrosion of tailgates, doors, hinges, pins, panels, brackets, load beds	Shorted or burned out control boxes, corroded wires, and connectors
Vibration (Macroscopic)	Engine mounts, cracked or broken axles and shafts, cracked bolts at seals	Cracked or inelastic shock absorbers, springs, leaf springs, wheel bearings	Bent or broken tailgates, doors, hinges, pins, panels, brackets, load beds	Broken wires, connectors, harness mounts

- Many damage mechanisms but no single correlation variable
- Part replacement plausibly restores the vehicle
- Existence of aging is uncertain

44

Observations:

- Aging is indicated by correlated failures (complete columns).
- An increase in failure rate above the peacetime baseline rate in one box may not be coherent aging but may merely indicate a design flaw.
- An increase in failure rate in one column would indicate that the design margin of an entire series of connected components is eroding.
- Correlated failure increases in two or more columns would indicate, with high probability, the aging of the entire vehicle.
- Failure in one column may typically precede failure in another.
- Smaller items often have a dominant failure mode (broken seals or bent pins). These items are not key indicators of aging, but an increase in consumption would indicate an increase in stress.



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RAND Analysis Summary

We have included a summary of RAND's published work on vehicle aging. This was requested by Mr. Johnson because aging relates to the topic of stress on equipment in OIF



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RAND Study: M1 Aging

- RAND's analysis
 - Assessed impact of age, location, and usage on individual (and subsystem) tank failures
 - Performed regression fits to Army maintenance data to create a model to show the impact of age
- Data culled from Army maintenance extracts
 - The Army TEDB
 - Platform type, year of maintenance, odometer, site information (division, location, battalion, company)
 - EDA
 - SAMS-2 daily deadline reports
 - Tank failure records
 - FedLog database
 - Tank part price data
- Additional post-processing required before analysis to impute missing data

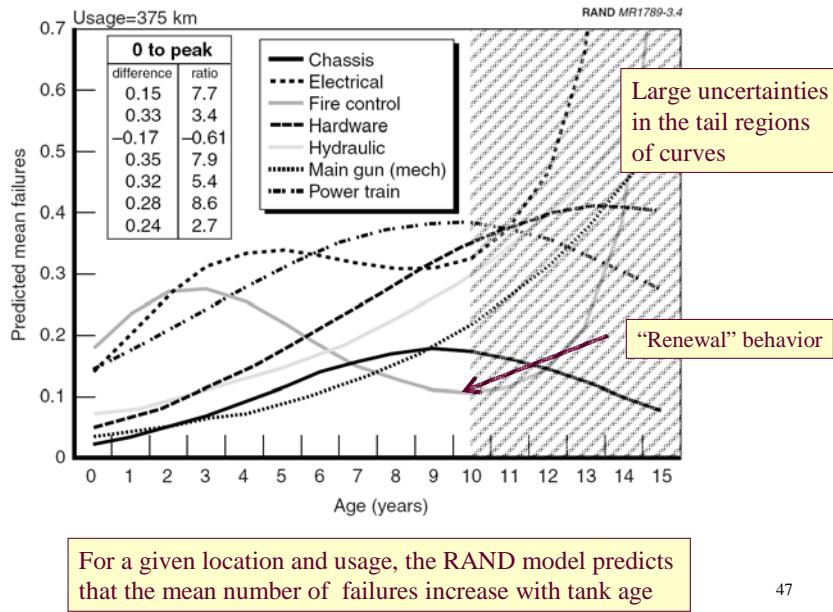
46

Peltz, E. Colabella, L. Williams, B. and Boren, P. (2004). *The Effects of Equipment Age on Mission-Critical Failure Rates: A Study of M1 Tanks*. RAND Corporation Monograph Report MR-1789. Available: http://www.rand.org/pubs/monograph_reports/2005/MR1789.sum.pdf

The Equipment Downtime Analyzer (EDA) is a RAND product implemented by the Army.

RAND Study: Predicted Mean Failures of Selected Subsystems by Age (Ft. Hood, 180 Days)

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47

For a given location and usage, RAND's model shows that mean failure rates increase with platform age. However, the uncertainty of the model's predictive ability is quite large when the age exceeds 10 years.

The "dips" in the failure rates may be due to

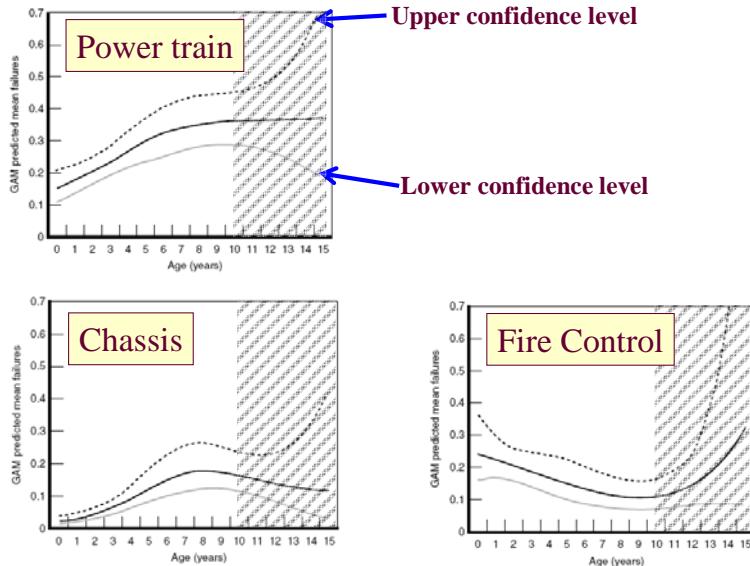
- Two different failure rates caused by a mix of M1A1 and M2A2 platforms
- Part failure and renewal. The first increase is the initial part failures. As parts are replaced, the overall failure rate decreases. With time, the new parts fail, and the failure rate increases again.

These theories have been posed as possible explanations. They have not been investigated. An alternate theory could be that they are due to bad fits because of the lack of statistics.

From the RAND paper:

It is possible for a subsystem to experience several such wear out/renewal cycles; cubic age-failure curves (for the electrical and fire control subsystems) may reflect this pattern. The steepness of these curves' tail regions must be interpreted with caution, though, as they are based on fewer data points than other portions of the curves. In practice, most fleets will not remain in the total Army fleet for a lengthy enough period to see many or even multiple wear out/renewal cycles. Thus, when the age-failure curve for a subsystem shows a plateau—or even a decrease—in the failure rate, it is probably an indication that sufficient fleet renewal for the subsystem has occurred to limit any further increase in the fleet failure rate. The renewal phenomenon should also be seen at the tank level. The model results suggest that at the tank level, it does not occur within the first 14 years of tank age, the range of our data.

RAND Study: 95% Confidence Bands for Model Predictions



48

This slide shows the results of an alternate model, which is a crosscheck on the quality of their parametric fits to the data. This alternate model is called a Generalized Additive Model (GAM).

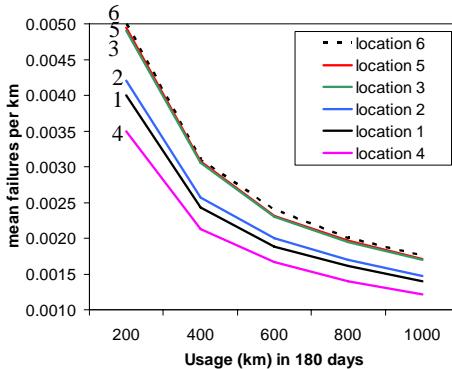
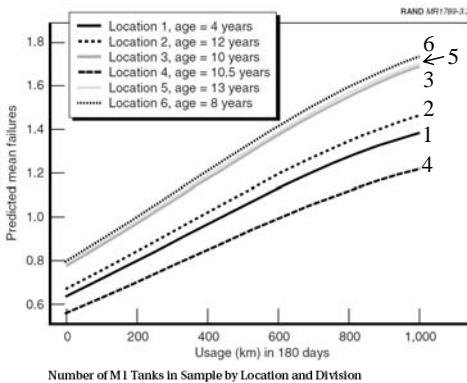
The RAND paper states that the GAM models give a more realistic fit to the power train, chassis, and Fire Control data, especially in the tail region.

These plots from the GAM show that in the tails of the distributions (i.e., for predictions beyond approximately the 10-year mark), the 95% confidence level bands grow large (i.e., diverge). For that reason, confidence is low that the model can predict what will happen as tanks age beyond 10 years. This effect is due to the lack of statistics on older tanks in the data.



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RAND Study: Predicted Mean Failures by Tank Usage and Location



Location Code	Location	Division(s)	Number of MIA1 Tanks	Number of MIA2 Tanks	
1	Fort Hood, TX	1st Cavalry (1CAV) 4th Infantry (4ID)	184	405	FORSCOM
2	Fort Carson, CO	4ID	58	—	FORSCOM
3	Korea	2nd Infantry (2ID)	141	—	EUSA
4	Europe	1st Infantry (1ID) 1st Armor (1AD)	355	—	USAEUR
5	Fort Riley, KS	ID IAD	175	—	FORSCOM
6	GA	3rd Infantry (3ID)	249	—	FORSCOM

NOTE: 3ID is stationed at Fort Stewart and Fort Benning, both of which are in Georgia.

- Large variance in the number of mean failures by location
- Predicted mean failures/kilometer fall with usage

49

Does this location dependence overshadow aging effects?

The plot in the upper left corner shows the predicted mean number of failures as a function of distance (kilometers) for vehicles (most of which are 10 years or older) in different locations. This plot shows a large difference in the mean number of failures for vehicles with similar usage and age as the location is varied. For example, while the tanks in locations 3 and 4 are similar in age (10 years and 10.5 years, respectively), the failure rate for tanks in location 3 is significantly larger than those in location 4 for the same amount of usage.

The plot in the upper right corner is the mean number of failures per kilometer as a function of usage (kilometers driven). As usage increases, the mean number of failures per kilometer falls.

The table in the lower left corner gives the density and MACOM information for each location.



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RAND Study: Selected Results

- A statistical correlation was established between year of manufacture and failure rates
 - Does not address correlation issues
- Significant variability in failure rate by location was observed, including variability within MACOMs
 - Underlying data have significant year-to-year variability
- RAND model predicts that the number of part failures per kilometer decreases with increasing usage
 - Does this indicate a regime of “underutilization”?
- Failure rates (or operational availability) and the cost of ownership are decoupled



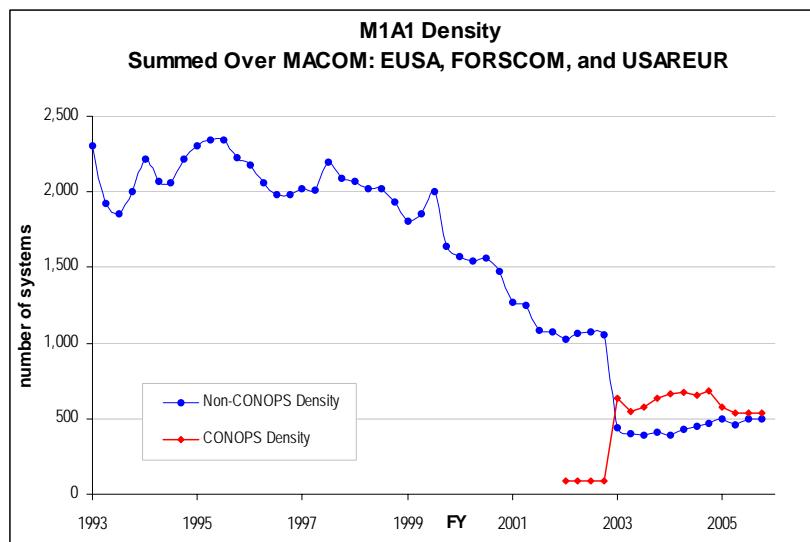
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OSMIS Backup

OSMIS Data: M1A1 Density



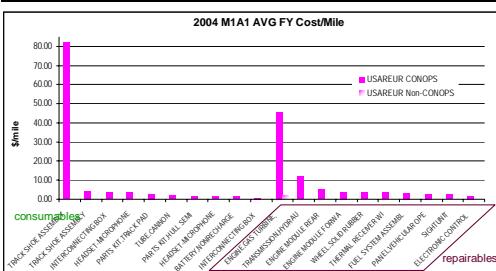
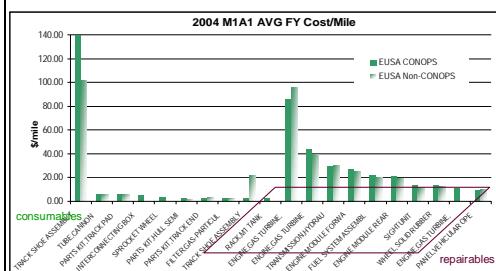
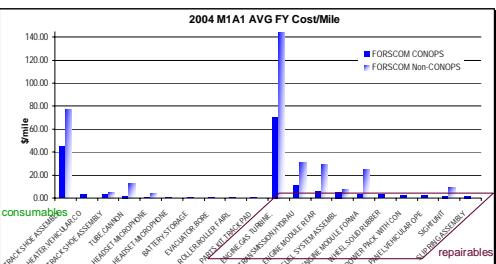
52



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OSMIS Data: M1A1 Cost (\$)/Mile by MACOM FY04

MACOM	Density		Miles/System	
	CONOPS	Non-CONOPS	CONOPS	Non-CONOPS
FORSCOM	276	271	1,107	645
EUSA	58	114	502	441
USAREUR	335	45	1,263	1,081



53

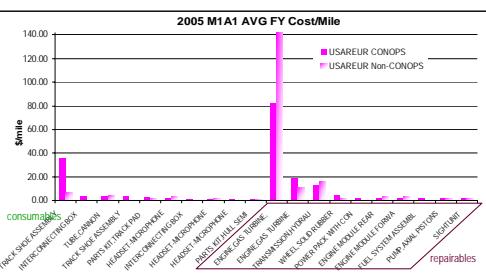
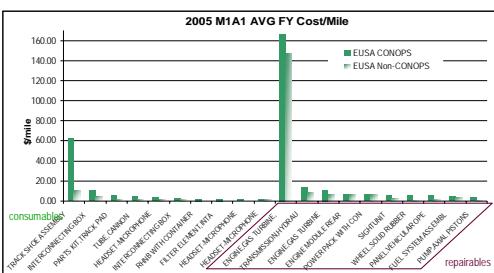
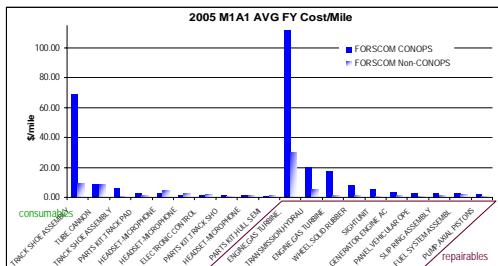
For USAREUR, of the top 10 consumable and repairable parts during CONOPS, only 5 parts total even appear within the top 50 ranked parts during Non-CONOPS. The Non-CONOPS costs for this command were much higher in 2005 (see next slide), suggesting that the anomalies in the data may be due to a deferral and catchup.



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OSMIS Data: M1A1Cost (\$)/Mile by MACOM FY 2005

MACOM	Density		Miles/System	
	CONOPS	Non-CONOPS	CONOPS	Non-CONOPS
FORSCOM	319	198	1,105	613
EUSA	60	99	1,014	801
USAREUR	165	191	790	642



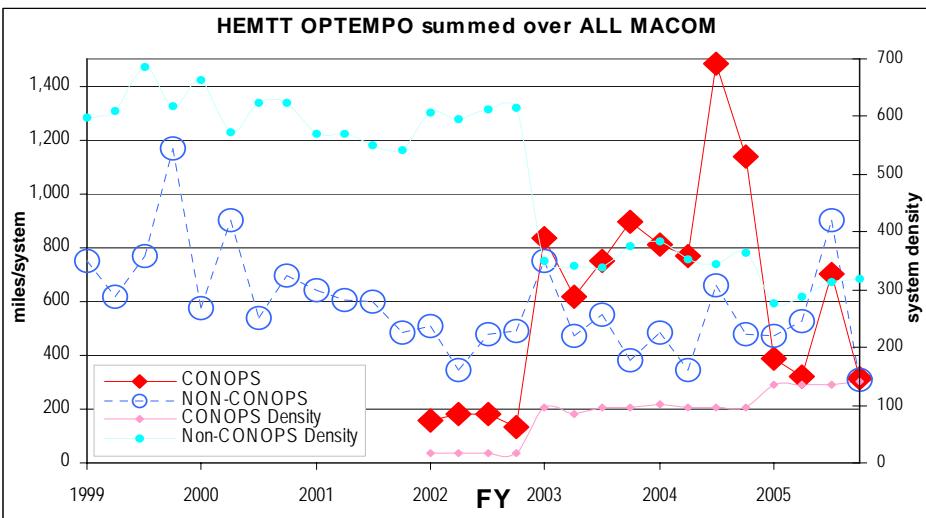
54

This slide displays the 2005 average cost per mile for the top 10 consumable and the top 10 repairable cost-driving parts during CONOPS for the M1A1 Abrams tank.

The OSMIS database shows that the NG has more tanks than all the other MACOMs together but that these NG tanks have apparently been driven less miles (7 to as much as 24 times less!) than the tanks belonging to the other MACOMs. These numbers would cause the Army National Guard (ARNG) cost/mile for the M1 to appear greatly inflated as compared to the other three MACOMs. In addition, the Tank-Automotive and Armament Command (TACOM) estimates that the number of ARNG tanks in Iraq was about 10 times less than the number reported here. These discrepancies led us to eliminate the ARNG data from this analysis.

While a slight variation exists in the top 10 cost drivers from MACOM to MACOM, the track shoe assembly is consistently the top-ranked cost-driving consumable part, and the gas turbine engine is the top-ranked repairable part during CONOPS and Non-CONOPS. We can determine that a lot more track shoes are burning out on the tanks deployed to Iraq. These plots make clear that the cost of the M1A1 is largely driven by the engines during CONOPS and Non-CONOPS for all MACOMs, although the engine costs increase during CONOPS only for FORSCOM and EUSA tanks.

OSMIS Data: HEMTT Usage



55

The HEMTT vehicle number in this data is M977-0260.

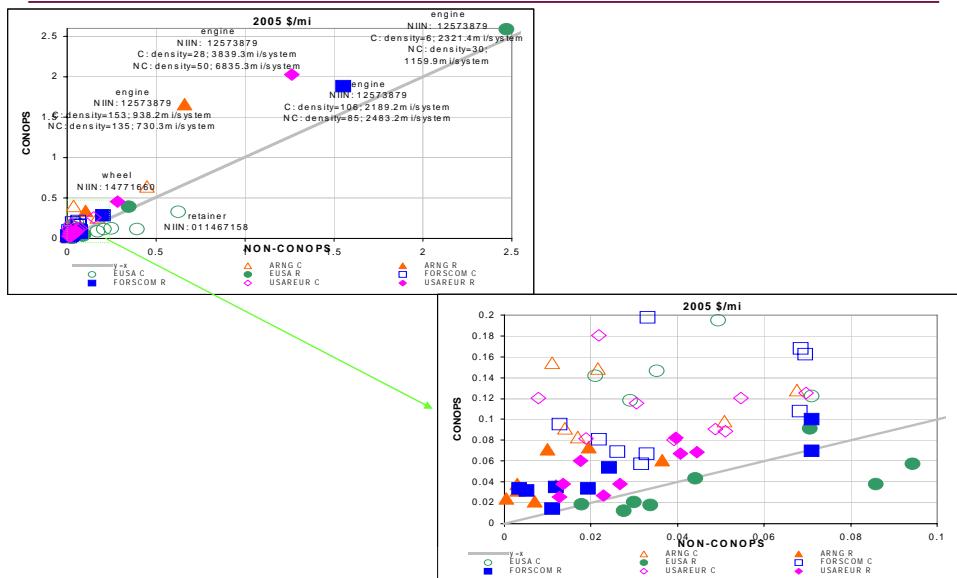
The density data clearly show the onset of the Global War on Terrorism and the beginning of OIF. (The beginning of OIF appears to show a loss of 200 HEMTT. This may be a data problem.) Both the peacetime and wartime data show significant variation in usage. The peak annual wartime usage was for 2004 and was just under 4,200 miles.

We do not see the same discrepancies in the ARNG for HEMTT as we do with M1A1.



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OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (1 of 3)



56

The plots in this slide display the CONOPS vs. the Non-CONOPS average cost (\$) per mile for the top 10 cost drivers for the HEMTT during 2005.

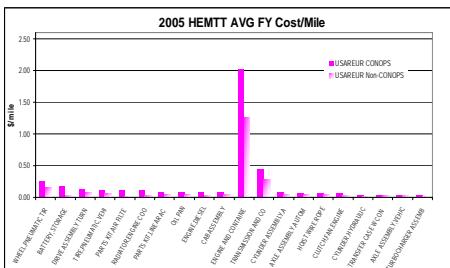
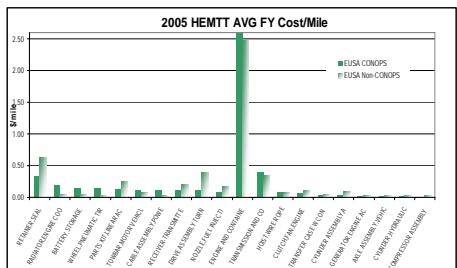
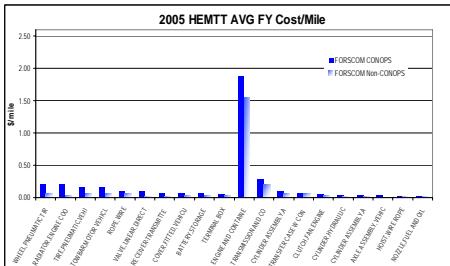
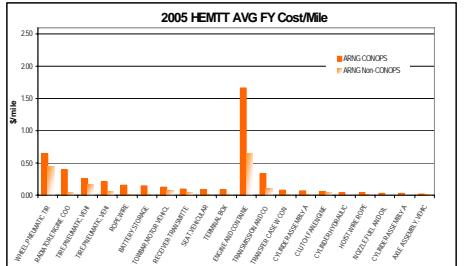
Each point represents one part. Parts from each MACOM are displayed in a different color. Consumable parts are represented by the open shapes, and repairable parts are represented by the solid shapes. A dashed line was included to represent where the CONOPS cost per mile is equal to the Non-CONOPS cost per mile. Points above the line indicate CONOPS costs greater than Non-CONOPS costs.

The EUSA costs for many types of consumable and repairable parts are higher during non-contingency operations.

These plots were created to enable the identification of systematic patterns between CONOPS and Non-CONPOS cost drivers that would indicate deterioration of the fleet. We did not identify any.



OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (2 of 3)

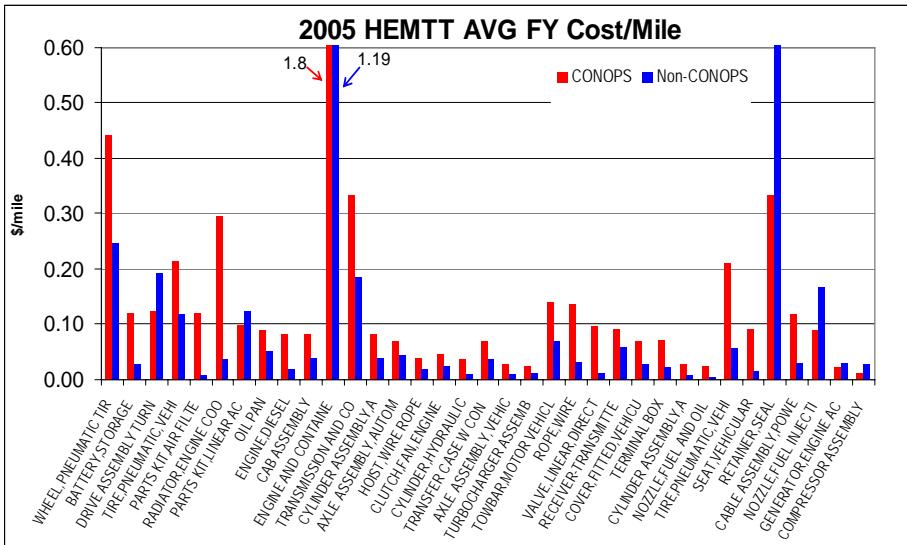


57

These are cost-driver slides, similar to those presented earlier for the M1s. In this case, we have no basis to exclude the NG data. The costs for CONOPS operations appear to be systematically higher than those for Non-CONOPS operations. The NG, FORSCOM, and USAEUR pattern of cost drivers is quite similar among the three commands and between CONOPS and Non-CONOPS for each of the three commands. The cost numbers show considerable variability.

The EUSA experience is quite different from the other three commands—at home and in theater. It also shows a different pattern between its experience at home and in theater. We were unable to deduce any conclusions relevant to aging from this data.

OSMIS Data: HEMTT Cost Drivers for CONOPS and Non-CONOPS (3 of 3)

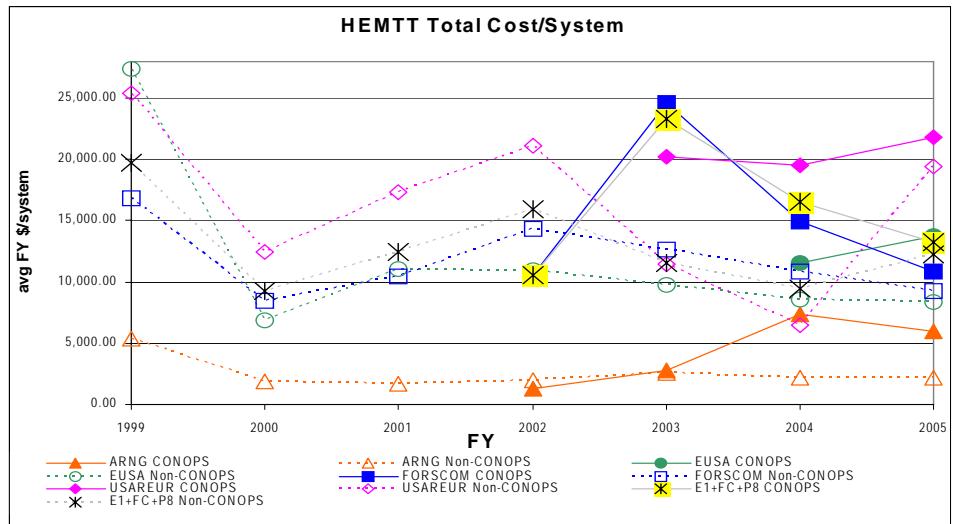


58

This slide shows the cost data for cargo HEMTTs in FY 2005, summed over the 4 commands shown previously (ARNG, FORSCOM, EUSA, USAREUR). On this slide, the repairables and consumables are presented together.

CONOPS costs are systematically higher. Note that the Non-CONOPS retainer seal cost for this year is an exception to the general rule about engines, transmissions, and tires dominating these costs.

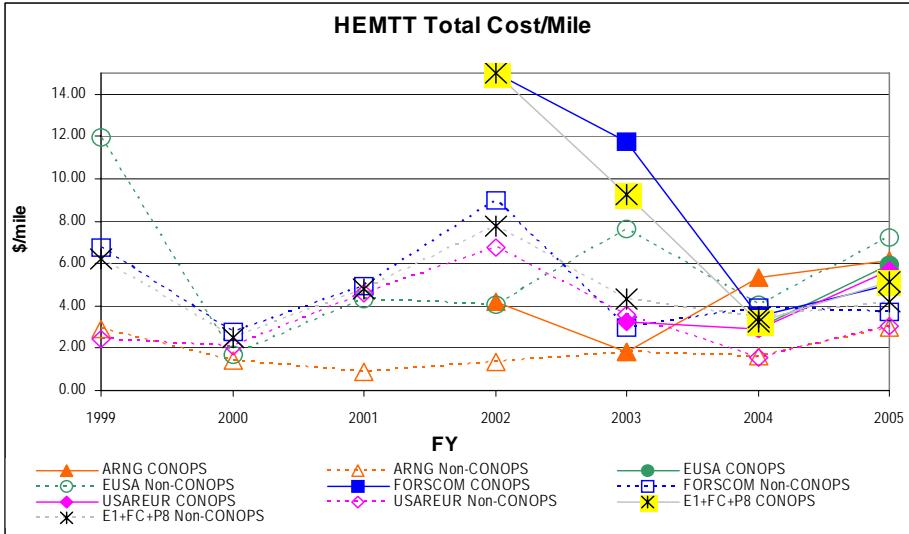
OSMIS Data: HEMTT Cost per System



59

This slide shows HEMTT total annual parts cost per system for the four commands and the sum of the three AA commands. Again, we have variability between commands and, over time, within commands. The situation becomes more confusing rather than less confusing after CONOPS begin.
Note: USAREUR CONOPS data begin in 2003, and EUSA data begin in 2004.

OSMIS Data: HEMTT Cost per Mile



60

This slide shows HEMTT cost per mile by year. The peacetime guard costs per mile are systematically low, but this difference is not present in the CONOPS data. **Note:** USAEUR CONOPS data begin in 2003, and EUSA data begin in 2004.



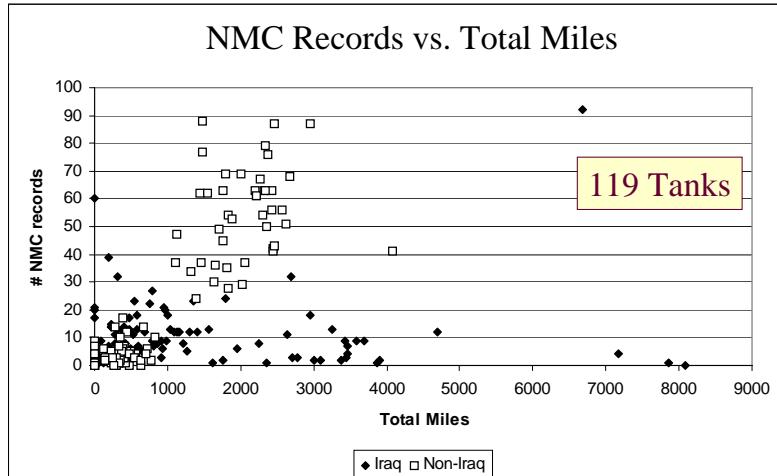
Science and Technology Division

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AMSAA Backup

AMSAA SDC Data: NMC Records vs. Miles



- The number of failures in Iraq is less than those at Ft. Hood
- In Iraq, no correlation of NMC failures with miles
- Large scatter in Ft. Hood data

62

The graph plots the mileage of the tanks at a location vs. the number of NMC records these tanks had at that same location. Each point represents a tank, and each tank has two points: one for Iraq and one for Non-Iraq (Ft. Hood or NTC).

A large number of points are located near the origin because of the number of records with zero mileage and the low number of records collected in Iraq.

The OIF data have three high-mileage, low-NMC points. The lack of correlation between mileage and number of NMC records persists even if these data points are removed, so the conclusion does not depend on these points. Nevertheless, the RAND reviewers view these points as raising questions about the global quality of the data, which might preclude any conclusions.

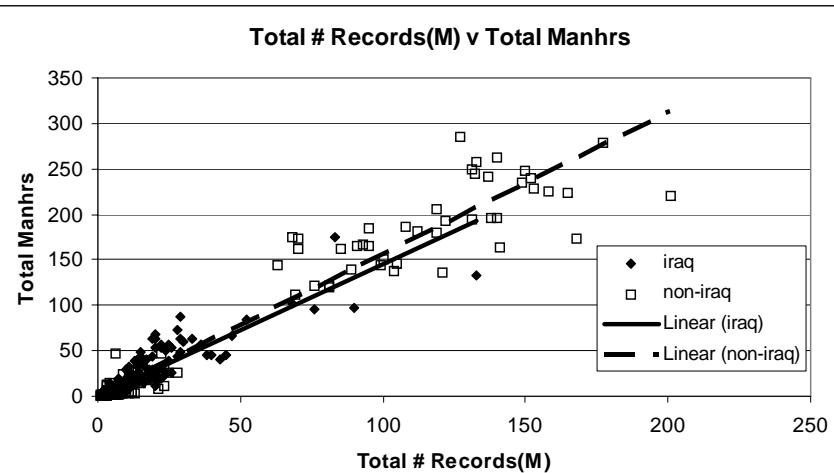
Notes:

- *Not all tanks with maintenance records had corresponding operational records. Moreover, not all tanks with operational records had operational miles recorded.*
- *The total number of tanks that have maintenance records in both Ft. Hood and Iraq and have corresponding operational records in both Ft. Hood and Iraq with non-zero operational miles is 47.*



Science and Technology Division

AMSAA SDC Data: Maintenance Man-hours vs. Records

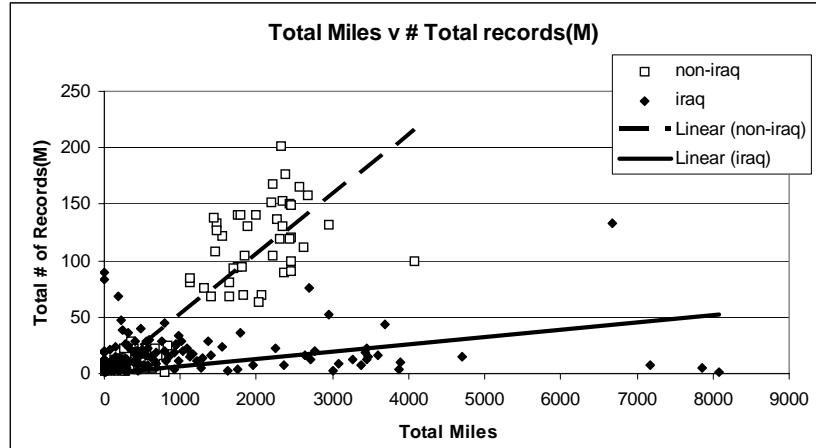


Maintenance man-hours in Iraq similar to those at Ft. Hood

63

The relatively large number of records for Ft. Hood compared with those for Iraq surprised us. We considered the possibility that multiple repairs might have been made in Iraq, with only a single record rather than one record per repair. We compared total maintenance man-hours with the total number of records on each of the tanks in the data set to see if the man-hours per record were larger in Iraq. There appears to be no significant difference.

AMSAA SDC Data: Total Miles vs. Number of Total Records (M) From Primary Dataset



64

This slide shows the relationship between total miles and total records for the primary data set (119 tanks). For Ft. Hood, the data are reasonably described by a linear relation. For Iraq, a linear fit has a near zero slope.

GLOSSARY

3ID	3 rd Infantry Division
AA	Active Army
AMSAA	Army Materiel Systems Analysis Activity
Ao	operational availability
AR	Army Reserve
ARNG	Army National Guard
CBO	Congressional Budget Office
CENTCOM	Central Command
CONOPS	concept of operation
CONUS	Continental United States
DoD	Department of Defense
EDS	Equipment Downtime Analyzer
EUSA	Eighth United States Army
FedLog	Federal Logistics
FORSCOM	U.S. Army Forces Command
FY	Fiscal Year
GAM	Generalized Additive Model
GAO	Government Accountability Office
HEMTT	Heavy Expanded Mobility Tactical Truck
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IDA	Institute for Defense Analyses
MACOM	Major Command
MRAP	Mine Resistant Ambush Protected
MTBF	mean time between failure(s)
MTTR	mean time to repair
NATO	North Atlantic Treaty Organization
NG	National Guard
NIIN	national item identification number
NMC	non-mission capable
NSN	national stock number
NTC	National Training Center
O&M	operations and maintenance

O&S	operations and support
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OPTEMPO	operating tempo
OSD	Office of the Secretary of Defense
OSMIS	Operating and Support Management Information System
PA&E	Program Analysis and Evaluation
POC	point of contact
SAMS-2	Standard Army Maintenance System-2
SDC	Sample Data Collection
TACOM	Tank-Automotive and Armament Command
TAMMS	The Army Maintenance Management System
TEDB	TAMMS Equipment Data Base
UAH	Up-armored High Mobility Multipurpose Wheeled Vehicle
USACEAC	U.S. Army Cost and Economic Analysis Center
USAREUR	United States Army Europe

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE <u>September 2007</u>	2. REPORT TYPE <u>Final</u>	3. DATES COVERED (<i>From-To</i>) <u>July 2007 – September 2007</u>			
4. TITLE AND SUBTITLE <u>Ground Vehicle Fleet Health</u>			5a. CONTRACT NUMBER <u>DASW01-04-C-0003</u>		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) <u>Isaac Chappell, Jenny Holzer, Phillip Koehn, Jenya Macheret, Dave Sparrow</u>			5d. PROJECT NUMBER		
			5e. TASK NUMBER <u>BA-2-1878</u>		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <u>Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882</u>			8. PERFORMING ORGANIZATION REPORT NUMBER <u>IDA Document D-3467</u>		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <u>OSD (PA&E) Defense Pentagon Room 2B256 Washington, DC 20301</u>			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT <u>Approved for public release; distribution is unlimited. (2 June 2008)</u>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <p>Operations in Iraq have resulted in increased, but still modest OPTEMPO on the Army's combat and tactical vehicles. Maintenance expenditures have also increased. We were asked to determine if available data showed clear evidence of any trends in fleet health. We looked at data from a variety of sources—the Operating and Support Management Information System (OSMIS), the Army Materiel Systems Analysis Activity (AMSAA) Sample Data Collection (SDC) and the Army's reported mission capable rates—to determine if there was evidence of deterioration in the Army's combat or tactical vehicle fleets. There is great variability in location-to-location and year-to-year experience, effectively obscuring any global trends. No evidence of deterioration was found, but the prospect could not be excluded.</p>					
15. SUBJECT TERMS <u>Stress on equipment, Army Reset Program</u>					
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON <u>Mr. Keith Kasperson</u>	
a. REPORT Uncl.	b. ABSTRACT Uncl.	c. THIS PAGE Uncl.	SAR	72	19b. TELEPHONE NUMBER (<i>include area code</i>) <u>703-697-2309</u>

